Consequences of Persistent Small-Scale Biological Structure on Upper Ocean Trophic Processes

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LONG-TERM GOALS

Our long-term goal is to quantify the interactions between small-scale biological and physical processes in the upper ocean. This project addresses that goal by examining the coherence in the distribution and variability of small-scale bio-optical properties with coincident spatial and temporal scales of physical properties and processes.

OBJECTIVES

Our scientific objective is to resolve temporal and spatial patterns in bio-optical and physical processes on those scales most relevant to planktonic organisms. Given the small size of planktonic organisms and the range of time intervals over which these organisms grow and reproduce, our objective requires observations that span centimeters to tens of meters in the vertical dimension, over time intervals of minutes to days. Integration of physical measurements with the biological measurements, on the same time and space scales, provides the opportunity to evaluate the trophic consequences of particular patterns of distribution and variability. We focus on our long-term objective by trying to unravel and further quantify the complex linkages between physical forcing and the observed distribution of thin layer properties. What range of conditions results in thin layer formation and persistence? What are the dominant processes that create and maintain small-scale structure? Over what time scales do features form, change, or disappear? Are particular coastal and oceanic habitats more or less likely to possess persistent small-scale features? What is the impact of these features on optical and acoustical signal transduction in the upper ocean? To what extent, and under what conditions, must we alter our sampling strategies to obtain acceptable, if not perfectly accurate, estimates of the distribution of physical, chemical, and biological properties and rate processes in the upper ocean?

APPROACH

We have addressed the objectives and questions outlined above through time-series deployments of a free-fall profiling system during cruises off the Oregon coast in 1997 and 1998. The instrumentation package has an adjustable fall speed so that we can resolve vertical patterns on scales less than 10 cm. Typically, we adjust the buoyancy on the profiling package to provide 2-3 cm resolution of physical and bio-optical properties during each profile. Repeated profiles (approximately 6 per hour) provide the time series necessary to define the temporal patterns of persistence of small-scale features. The

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profiling package is designed so that the instrumentation configuration can be modified easily. The deployment configuration used in these field experiments has consisted of a Sea-Bird 911 CTD, dual multi-wavelength absorption and attenuation meters (ac-9), a multi-wavelength spectrofluorometer which measures dissolved colored organic matter (SAFIRE), a data acquisition system (MODAPS), an Acoustic Doppler Velocimeter (ADV), and a rosette system for obtaining discrete samples during profiling. In addition, we deploy a thermistor chain to record temperature flucuations due to the passage of internal waves and record the vertical structure of horizontal currents with the shipboard Acoustic Doppler Current Profiler (ADCP).

WORK COMPLETED

During FY2000 we continued our analysis of data obtained during a 14-day cruise in September 1997 and a 21-day cruise in September 1998. During each of these field operations, we conducted time-series observations at three locations off the coast of Oregon. We focussed on a mid-shelf station (16 km from shore), a shelf-break station (50 km from shore), and an offshore station (200 km from shore). At each of these stations, we deployed a thermistor chain to record internal wave activity while recording the vertical pattern of horizontal currents with the shipboard Acoustic Doppler Current Profiler. We obtained several hundred high-resolution profiles of the upper water column with our free-fall profiler, and were able to obtain discrete samples with our mini-rosette system during free-fall profiling. Data analysis from the 1997 and 1998 cruises is now complete and we are preparing manuscripts for submission.

RESULTS

Internal Waves

We have observed a wide range of internal wave activity at all locations, resulting in vertical displacements of 5-10m within 10min intervals. These rapid displacements altered the small-scale vertical patterns of phytoplankton distribution but rarely lead to mixing over these small vertical scales.

Thermistor chain data summaries for the 1997 and 1998 cruises can be found at:
http://argon.oce.orst.edu/web/biooptics/projects/ssbs/results/tchain/tchain.htm

Relationship of small-scale horizontal velocity and vertical phytoplankton distribution

As mentioned above, our unique profiling system can detect vertical differences in horizontal velocity (relative to the profiler, using the Sontek Acoustic Doppler Velocimeter) while simultaneously measuring temperature, salinity, and optical properties. We have found a remarkable coherence between the small-scale velocity gradients and the vertical structure of density and phytoplankton (Figure 1).

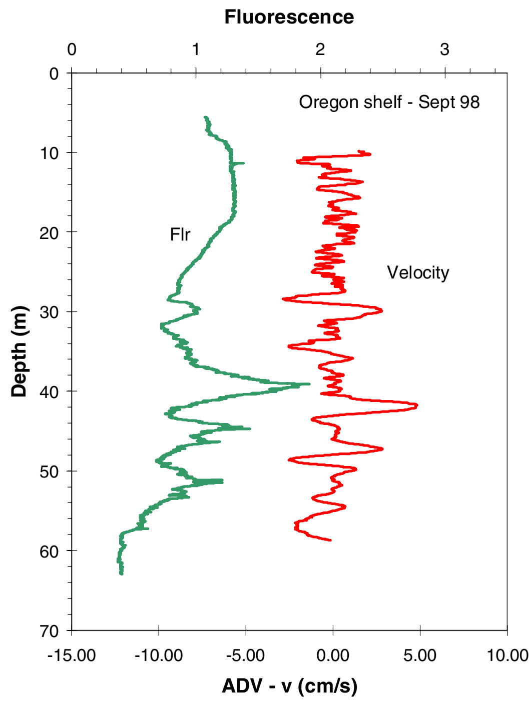

Figure 1. Vertical profile of chlorophyll fluorescence and horizontal velocity from the ADV. Note the coherence between the local maxima in fluorescence and the velocity gradient near that local maximum.

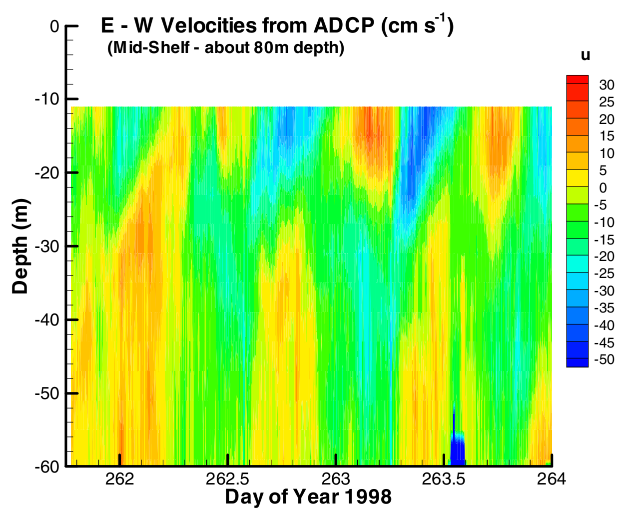

Figure 2. September 1998 onshore-offshore flow at the mid-shelf location (80m depth) from moored ADCP. Note the strong shear between 20–30m during changes in the tidal cycle.

We found that vertical gradients in horizontal velocity defined the vertical pattern in phytoplankton fluorescence when local stratification kept the Richardson number greater than about 0.05. We also found that sharp vertical gradients in biomass occurred even in the presence of strong tidal velocity changes, as revealed by the time series of ADCP records over the mid-shelf location off the Oregon coast (Figure 2).

These observations of linkages between velocity shear and phytoplankton thin layers over the continental shelf are important steps in refining our understanding of small-scale structure in a range of oceanic environments, from relatively protected coastal areas such as East Sound, WA, to open continental shelf areas such as that studied in this project.

Additional information about these cruises and the data sets can be found at : http://argon.oce.orst.edu/web/biooptics/projects/ssbs/ssbs.htm

IMPACT/APPLICATION

Our instrumentation suite and observational approach provide the opportunity to extend our understanding of the response of planktonic assemblages to physical forcing across a range of time and space scales. In particular, we must extend our observations of the link between the vertical scales of horizontal velocity changes and patterns of small-scale planktonic structure. It is clear from our results that our understanding of plankton dynamics requires us to shift our attention from *vertical* processes to *horizontal* processes. This will present new challenges over the next few years.

TRANSITIONS

The two open ocean cruises with this instrumentation suite has prepared us for more extensive observations of horizontal scales of persistent small-scale structure. We will be using the free-fall profiling system during cruises off the Northern California and Oregon coasts in 2000 and 2001 as part of the CoOP and GLOBEC programs.

RELATED PROJECTS

This project is jointly supported by the Office of Naval Research and the National Science Foundation, Division of Ocean Sciences. Drs. Evelyn and Barry Sherr are co-investigators on the NSF portion of this work.

This ongoing work is also related to the Thin Layer experimental work in East Sound, WA, where we have direct field collaborations with the following ONR Principal Investigators:

Dr. Percy Donaghay, University of Rhode Island
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